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13SEP02 E747687-1 D02776
P700 0.00-0221099.5

2. Patent application number *(The Patent Office will fill in this part)* — 0221099.5

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

QINETIQ LIMITED

Registered Office 85 Buckingham Gate
London SW1E 6PD
United Kingdom

Patents ADP number *(if you know it)* — 8183857001

If the applicant is a corporate body, give the country/state of its incorporation — GB

4. Title of the invention — Microwavable Packaging Material

5. Name of your agent *(if you have one)* — Robert William Obee

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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Country	Piority application number *(if you know it)*	Date of filing *(day / month / year)*

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Continuation sheets of this form	
Description	6
Claim*(s)*	2
Abstract	
Drawing*(s)*	3

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	1 + 3
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
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1. I / We request the grant of a patent on the basis of this application.

Signature R W Obee, Agent for the Applicant Date 10/9/02

2. Name and daytime telephone number of person to contact in the United Kingdom Mrs Linda Bruckshaw 01252 392722

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DUPLICATE

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MICROWAVABLE PACKAGING MATERIAL

The present invention relates to a material for use in packaging or otherwise covering objects for microwave heating. The invention is more particularly concerned with a material for use in microwavable food packaging although it may also find application in, for example, bandages and patches adapted to be worn on the body during microwave heat treatment of sports injuries and the like.

Conventional microwavable food packaging consists of polymeric or paper-based materials which are transparent to microwave radiation. The use of electroconductive materials, such as metal foils, within microwave ovens (typically operating at around 2.45 GHz) is generally to be avoided as they are inherently reflective to microwave radiation and can cause arcing within the cavity and risk destruction of the magnetron. On the other hand, it would be desirable to incorporate a low emissivity (ie highly reflective) metal foil in the packaging of chilled and frozen microwavable foodstuffs as such a material can reduce the transfer of heat due to thermal infrared (IR) radiation (3-5 micron wavelength range) or in other words enhance the thermal insulation properties of the packaging. This would usefully prolong the time for which the foodstuff can remain cool or frozen e.g. between being purchased and refrigerated at home. Similarly, the incorporation of such a foil would tend to keep the foodstuff hotter for longer after heating in the package.

The present invention is predicated on the recognition that it is possible to utilise the desirable IR reflective properties of a metal foil in a microwavable packaging material if it is configured as a so-called frequency selective surface (FSS). This expression refers to the known characteristic that a structure composed of a periodic array of suitably dimensioned electroconductive patch elements can behave as a filter to incident radiation, transmitting at lower frequencies and reflecting at higher frequencies.

The invention accordingly resides in a material for use in covering objects for microwave heating comprising a substrate substantially transparent to microwave radiation bearing a periodic array of low emissivity metal patch elements defining a frequency selective surface adapted to pass microwave radiation and reflect thermal infrared radiation. Preferably the characteristic dimension of the patch elements is no greater than about 1600 microns (or more preferably no greater than about 500 microns), the spacing between the patch elements is no greater than about 200 microns (or more preferably no greater than about 100 microns) and the emissivity of the material comprising substrate and patch elements is no

greater than about 0.4 (or more preferably no greater than about 0.2) in the 3-5 micron wavelength range.

The invention also resides in: a package or packaging material for microwavable foodstuff comprising a material as defined above; a packaged microwavable foodstuff wherein the package comprises a material as defined above; a bandage or patch adapted to be worn on the body comprising a material as defined above; and a method of heating an object which comprises covering the object with a material as defined above and exposing the material to microwave radiation.

By virtue of the IR reflectivity conferred upon a material according to the invention by the metal (preferably aluminium) patch elements, a chilled or frozen foodstuff packaged in such material may be kept cool or frozen while out of refrigeration for longer than the conventional packaging, but can still be heated in a microwave oven in the same packaging by virtue of the microwave transparency of the FSS. The low emissivity patches may also keep the heated food warmer after microwave exposure, allowing a reduction in the traditional "standing" time which is required for the temperature of microwaved food to even out, increasing the effectiveness of the temperature equalisation during standing, and/or allowing the food to stand for longer before being served hot. The same attribute may increase the versatility of microwave cooking. For example retention of heat in the packaging may allow steaming of food or even cooking from raw.

There may be additional advantages in having a high proportion of the substrate's surface area covered by the metal patches. The metal may act as a barrier to chemical migration and permeation of oxygen into the food, leading to enhanced shelf life. The patches may also have significant reflectivity in the visible light band, which may be considered to enhance the aesthetic appeal of the packaging, and limiting the transmission of light into the packaging may resist discolouration of the food. In this case an optically transparent substrate may be used instead of the translucent or opaque substrates in conventional microwavable food packaging while the FSS may still permit sufficient light transmission to enable the food to be viewed through the packaging.

The invention will now be more particularly described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a plan view of a portion of a preferred embodiment of microwavable food packaging material according to the invention;

Figure 2 is a section on the line II-II of Figure 1;

Figure 3 illustrates the reduced experimental heat loss through a material according to the invention; and

Figure 4 is a section through one form of a microwavable foodstuff package according to the invention.

Referring to Figures 1 and 2, the illustrated embodiment of a microwavable food packaging material according to the invention comprises a microwave-transparent polymer film 1 of, for example, polyester, polypropylene, polyethylene or nylon, upon which is formed a frequency selective surface (FSS) composed of a periodic array of electroconductive patch elements 2 of, for example, aluminium, copper, gold, titanium or chromium. The patch elements are in this case square in shape, although other shapes are possible, for example rectangles, hexagons, circles or crosses. The purpose of the FSS is to pass microwave radiation, to permit heating in a conventional microwave oven of a foodstuff in a package made from the material, while conferring on the material a sufficiently low emissivity in the thermal IR wavelength range to provide a useful degree of thermal insulation to the contents of the package. These attributes are achieved as follows.

For an FSS to pass radiation of a given frequency it is known that the individual patch elements must be substantially dimensionally smaller than the wavelength at which transparency is required. A conventional design formula is to make the characteristic patch dimension (*d* in the case of Figure 1) effectively less than 1/10 of a wavelength. The wavelength of radiation generated in a conventional microwave oven operating at 2.45 GHz is approximately 12 cm, so conventional design practice suggests a characteristic patch dimension up to 1.2 mm for an FSS to be transparent to such radiation. This does not, however, taken into account the conditions which are likely to prevail in practice in use of a material according to the invention. That is to say, in the course of microwave heating of a foodstuff in a packaging material of this kind it is likely that the material will be in contact with the food over significant areas. Even with the FSS on the external surface the food will be separated from the patch elements only by the thickness of the substrate 1 (typically 20-50 microns) and the close proximity of the foodstuff to the FSS will negatively influence its transparency by virtue of the high relative dielectric permittivity, ε_r, (typically $\varepsilon_r = 60$) of the adjacent food medium. More particularly we believe that to compensate for the effect of areas of the packaging material touching the food the maximum theoretical characteristic

patch dimension of 1.2 mm derived above should be reduced by a factor of root 60, leading to a maximum dimension of approximately 1600 microns. As an additional safety factor, however, to guarantee substantial transparency of the FSS under all likely operational conditions we prefer to limit the characteristic patch dimension *d* to no greater than about 500 microns. This will also ensure that in the event of an accidental short circuit between two adjacent patch elements caused by a flaw or defect in the manufacturing process the combined patch size will not cause a significant interaction with the microwaves.

To minimise the emissivity of the illustrated material it is desirable that as much as possible of the surface area of the substrate 1 is covered by metal or in other words that the separation distance *s* between adjacent patch elements 2 is kept as small as possible, subject to practical manufacturing tolerances. We prefer that the separation distance between adjacent patches is no greater than 200 microns and more preferably is 50 - 100 microns. In an example where *d* is 400 microns and *s* is 100 microns (ie where approximately 65% of the substrate surface is metallised), if the substrate 1 is polyester with an emissivity of 0.98 and patches 2 are aluminium with an emissivity of 0.1 in the thermal IR waveband then the emissivity of the combined material is (0.65 x 0.1) + (0.35 x 0.98) or approximately 0.4. The combined emissivity can be reduced by increasing the percentage of metallised surface area (by increasing the patch size and/or reducing the separation) so with, say, 90% of the substrate surface covered by the patches the emissivity using the same materials as above reduces to (0.9 x 0.1) + (0.1 x 0.98) or approximately 0.2.

The precise thickness of the patch elements 2 is not considered critical, provided that it is above the skin depth necessary for the metal to interact with radiation in the thermal IR waveband and not so great as to affect the microwave transparency of the FSS. In theory this means that these elements can be between nanometres and several tens of microns in thickness. The lower limit of thickness is set by the skin depth ie the depth to which radiation penetrates the surface of the chosen metallic coating. This can be calculated theoretically using well documented formulae being inversely proportional to the square root of the product of the conductivity of the metal (σ) and frequency of the radiation (f). Using published values for the dc conductivity of aluminium (σ=3.54x10^{-7} mho/metres) and a frequency in the middle of the infra-red band (f=7.5x10^{13}Hz) a skin depth of approximately 10nm is suggested. In practice, however, other issues are likely to determine the chosen thickness of the metallic coating, such as the consistency of the deposition technique, the quality of the deposited metal and cost of the deposited metal. These factors suggest a practical minimum thickness of several tens of nanometres.

It is envisaged that materials according to the invention may be manufactured in bulk in several different ways. Vacuum-coated aluminium-on-polymer films are already in common use as non-microwavable food packaging, eg for potato crisp (in USA chips) and similar snack food packets, and an existing material of this kind may be taken as the starting point in the following process. An etch-resistant ink is gravure printed onto the metal surface of the existing film in a pattern corresponding to the patch elements in the desired FSS configuration. The material is then chemically etched with a standard solution such as sodium hydroxide, hydrochloric acid or ammonium peroxodisulphate to remove the exposed metal between the desired patches. The ink can then be removed from the resultant patches by a suitable solvent if required, although this may not be necessary if the ink is itself sufficiently IR-transparent not to affect the IR reflectivity of the patches.

Alternatively the patch elements can be deposited onto the polymer substrate in the desired FSS configuration from the outset by vacuum coating (eg sputtering) the metal through a mask which leaves portions of the substrate uncoated around each patch.

A third process would be to make use of a metal foil with a heat-sensitive adhesive backing. Such materials are readily available and currently used as the basis of "glittery" gift wraps and similar products. In this case a heated stamp with a pattern corresponding to the patch elements in the desired FSS configuration is used to bond the foil to the substrate, leaving non-bonded portions which are physically stripped away to leave the substrate uncoated around each resultant patch.

To demonstrate the potential thermally insulative properties of a material according to the invention the following experiment was performed. Approximately 150 ml of water in a typical thermoformed polystyrene beaker was heated to a temperature of 65°C in a microwave oven. The beaker was removed from the oven and stood at room temperature and the temperature of the water was monitored over a period of five minutes, without stirring. This process was repeated with the external surfaces of the beaker covered with an aluminium FSS-coated polymer film material substantially as previously described with reference to Figures 1 and 2. No lids were used in either case. The resultant cooling curves are shown in Figure 3, with the water temperature expressed as a fraction of the initial (microwave-heated) temperature, and demonstrate that heat loss was significantly reduced by the presence of the FSS film.

Figure 4 illustrates one form of a microwavable package according to the invention for a foodstuff 3. It comprises a semi-rigid tray 4 moulded from a conventional polymeric

microwavable food packaging material with an FSS-coated polymer film 5 such as described with reference to Figures 1 and 2 laminated on its exterior, and an FSS-coated polymer film 6 such as described with reference to Figures 1 and 2 closing the top of the tray. If desired the tray 4 can be formed into a number of different compartments covered by respective FSS-coated films configured to provide different levels of microwave transparency and/or infrared reflectivity so as to optimise the heating conditions for different foodstuffs in the different compartments when exposed to the same microwave energy. The package could also include so-called microwave susceptors, which are discrete metal elements, not to be confused with an FSS patch array, which heat up when exposed to microwaves to produce browning effects in accordance with known techniques. FSS-coated films such as described with reference to Figures 1 and 2 may also be formed into flexible bags for packaging of micowavable foodstuffs, or pouches for the heating of home-prepared foods.

CLAIMS

1 A material for use in covering objects for microwave heating comprising a substrate substantially transparent to microwave radiation bearing a periodic array of low emissivity metal patch elements defining a frequency selective surface adapted to pass microwave radiation and reflect thermal infrared radiation.

2 A material according to claim 1 wherein said array is substantially transparent to radiation in the region of 2.45 GHz.

3 A material according to claim 1 or claim 2 wherein the characteristic dimension of said patch elements is no greater than about 1600 microns, the spacing between said patch elements is no greater than about 200 microns and the emissivity of the material comprising substrate and patch elements is no greater than about 0.4.

4 A material according to claim 3 wherein the characteristic dimension of said patch elements is no greater than about 500 microns, the spacing between said patch elements is no greater than about 100 microns and the emissivity of the material comprising substrate and patch elements is no greater than about 0.2.

5 A material according to any preceding claim wherein said substrate comprises a film of polyester, polypropylene, polyethylene or nylon.

6 A material according to any preceding claim wherein said patch elements are composed of aluminium, copper, gold, titanium or chromium.

7 A material according to any preceding claim wherein said patch elements are in the shape of squares, rectangles, hexagons, circles or crosses.

8 A packaging material for microwavable foodstuff comprising a material according to any preceding claim.

9 A package for microwavable foodstuff comprising a material according to any one of claims 1 to 7.

10 A packaged microwavable foodstuff wherein the package comprises a material according to any one of claims 1 to 7.

11 A bandage or patch adapted to be worn on the body comprising a material according to any one of claims 1 to 7.

12 A method of heating an object which comprises covering the object with a material according to any one of claims 1 to 7 and exposing the material to microwave radiation.

13 A method of manufacturing a material according to any one of claims 1 to 7 which comprises: taking a material comprising a substrate substantially transparent to microwave radiation upon which is vacuum deposited a continuous metal foil; applying an etch-resistant substance to the metal foil in patches corresponding to said array; and chemically etching away the metal exposed between the patches of etch-resistant substance.

14 A method of manufacturing a material according to any one of claims 1 to 7 which comprises vacuum depositing a metal onto a substrate substantially transparent to microwave radiation through a mask with a pattern corresponding to said array.

15 A method of manufacturing a material according to any one of claims 1 to 7 which comprises: taking a material comprising a metal foil with a heat-sensitive adhesive backing; bonding said foil to a substrate substantially transparent to microwave radiation with a heated stamp having a pattern corresponding to said array; and removing the portions of said foil left unbonded by said stamp.

16 A material for use in covering objects for microwave heating substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

17 A package for microwavable foodstuff substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

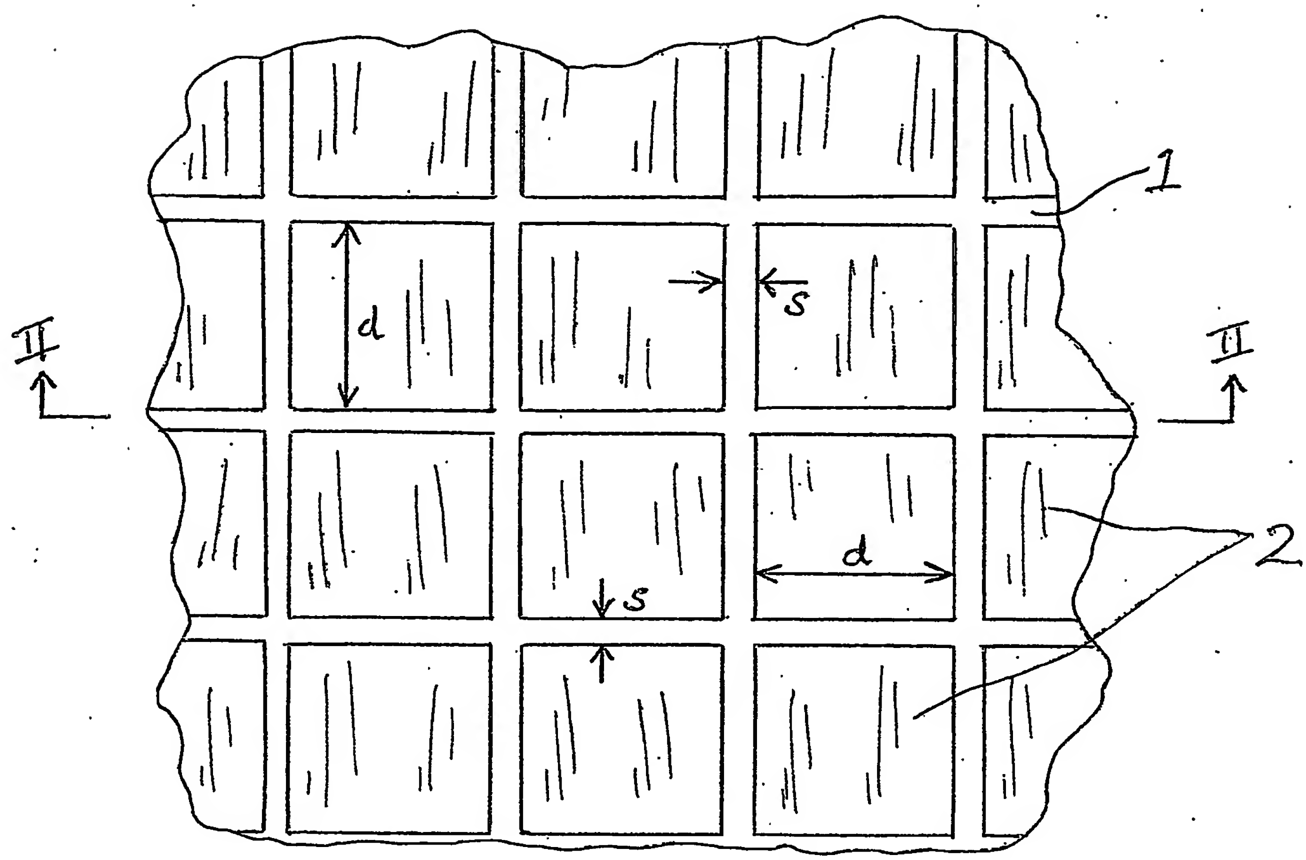

Fig. 1

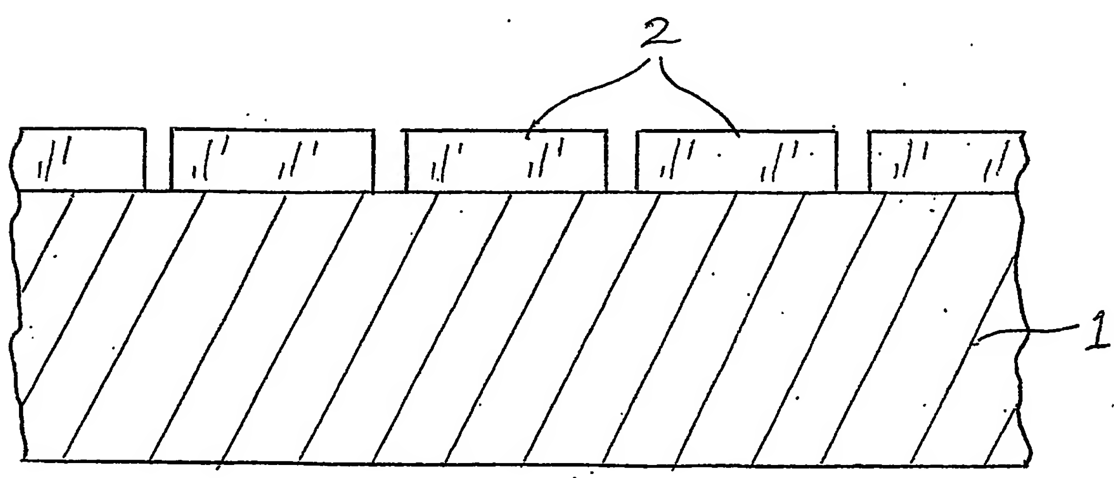

Fig. 2

Cooling Curves for Water Containers with and without FSS Coated Film

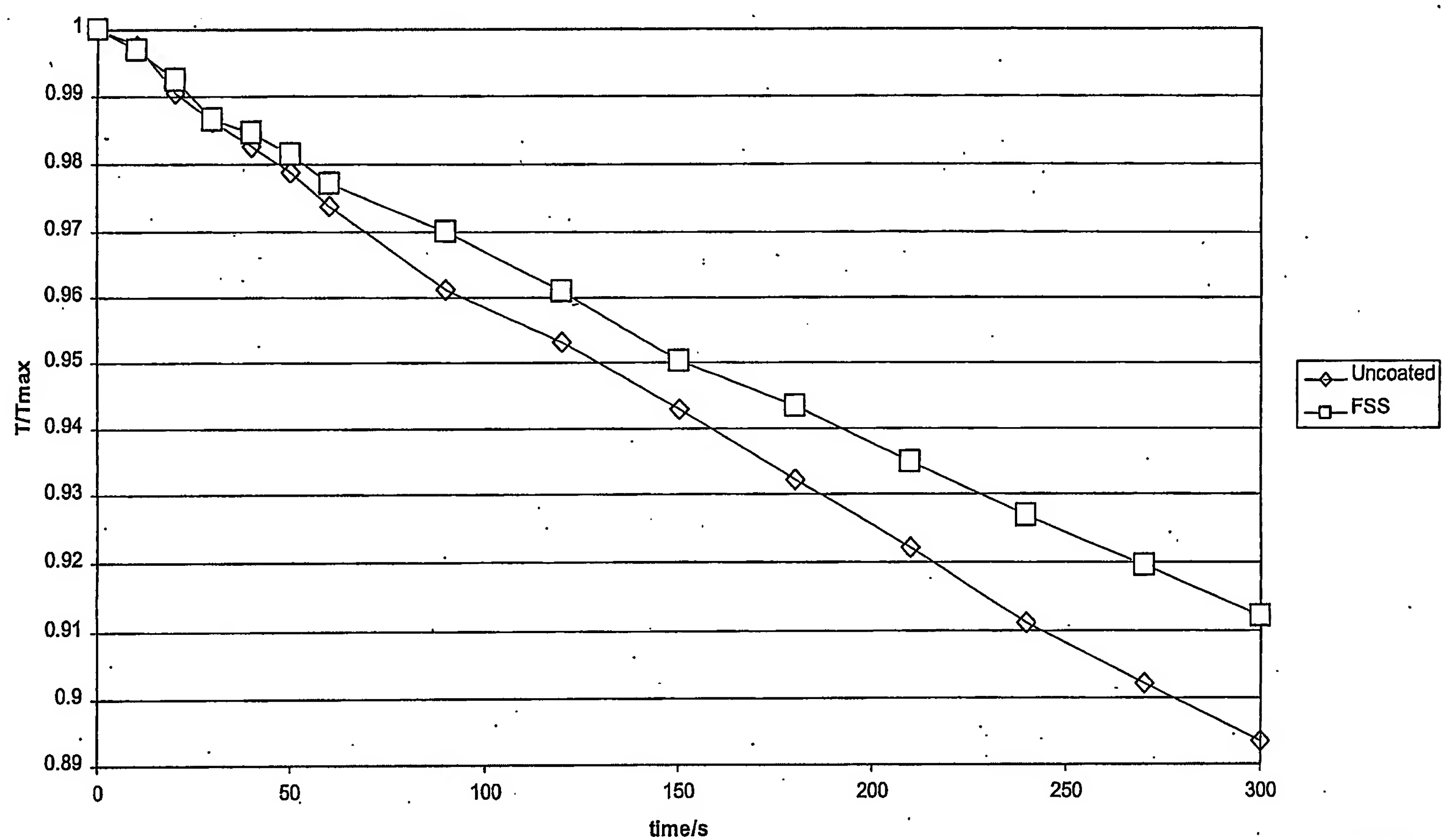

Fig.3

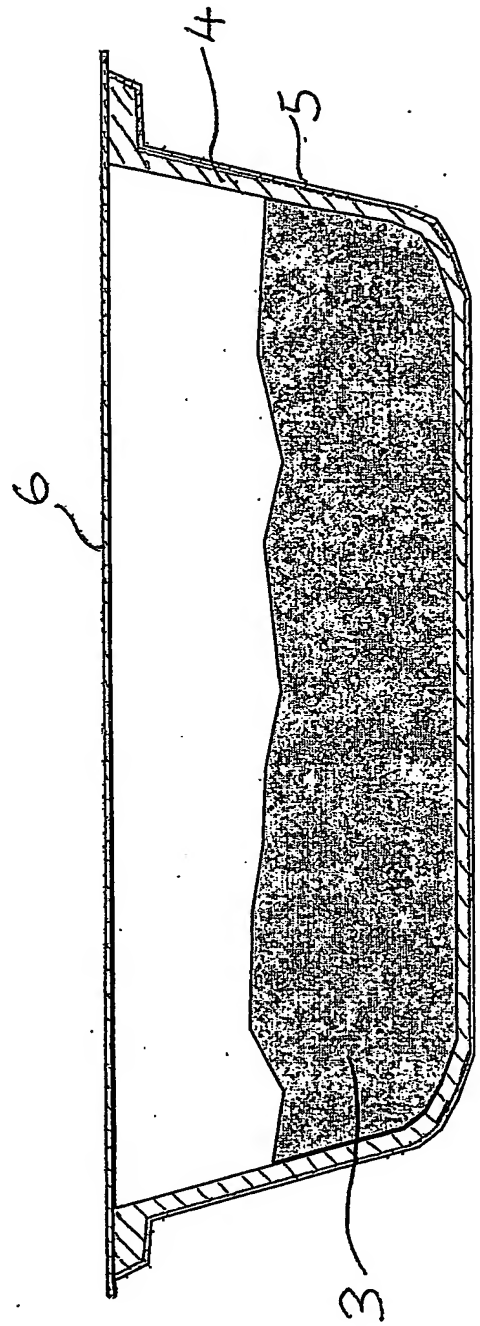

Fig.4

PCT Application
GB0303861